SUPSI

Advances in Software Systems for Environmental Decision Making

ISESS 2013, Neusiedl am See, 9-11 October

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USI/SUPSI

Your speaker: declaration of my conflict of interest!

iEMSs 2014
International Congress on Environmental Modelling and Software

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Bold Visions for Environmental Modelling

San Diego, California June 15-19, 2014

Abstract Submission is Now OPEN!

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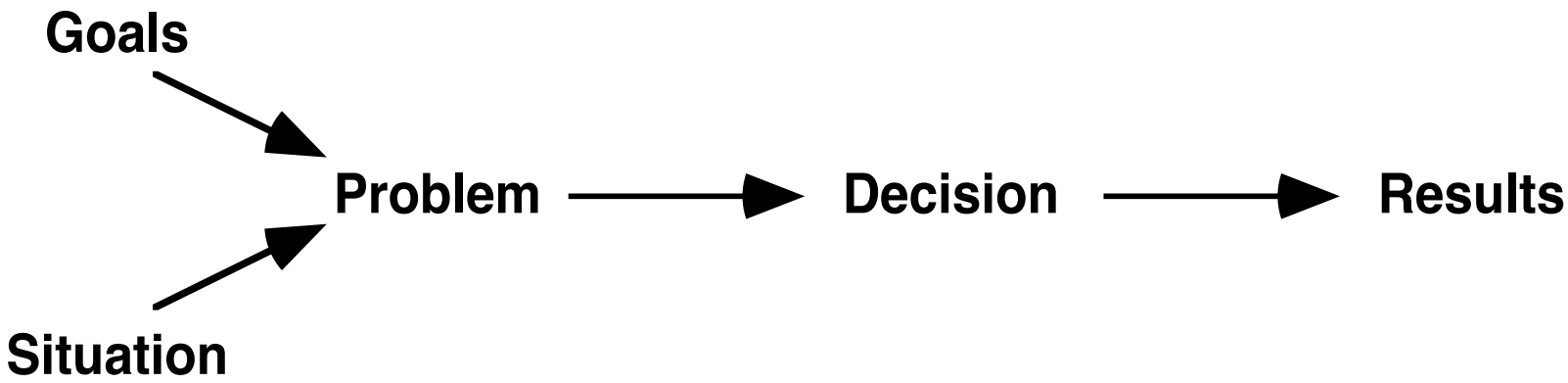
8th International Congress on Environmental Modelling and Software (iEMSs)
June 15-19, 2014, San Diego, California, USA

Bold Visions for Environmental Modelling

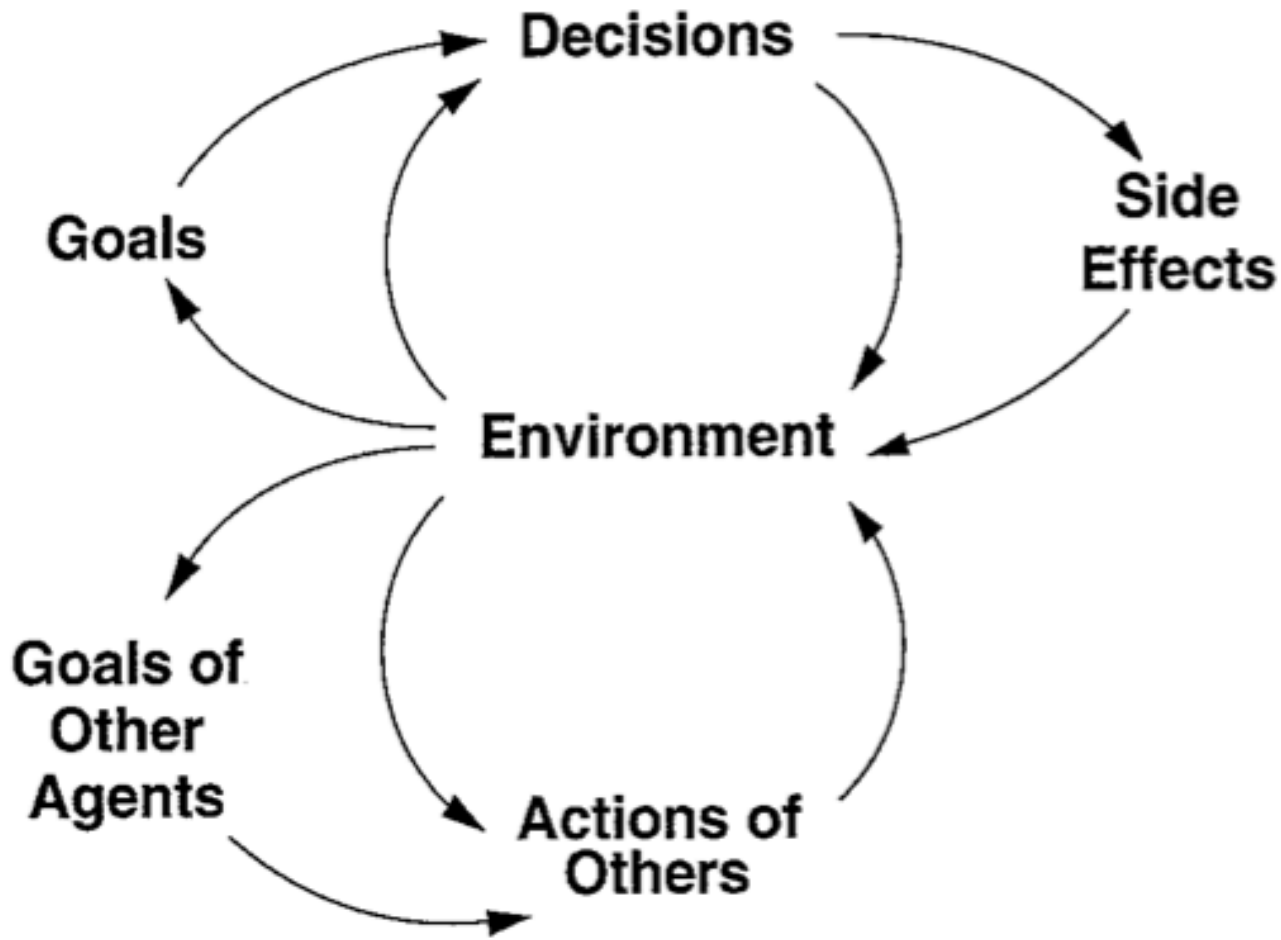
Dear Colleague,

Outline

- What are EDSSs and their role in the decision making process
- The past and the present: how EDSSs are structured and how they work
- New approaches: from data to people, from people to data
- If time allows: a review on how DSSs are used in the real world



[Sterman 2000]



[Sterman 2000]

Characteristics of environmental decision problems

multiple and conflicting objectives

multiple decision makers

uncertainty in cost function

uncertainty in model structure

uncertainty in model parameters

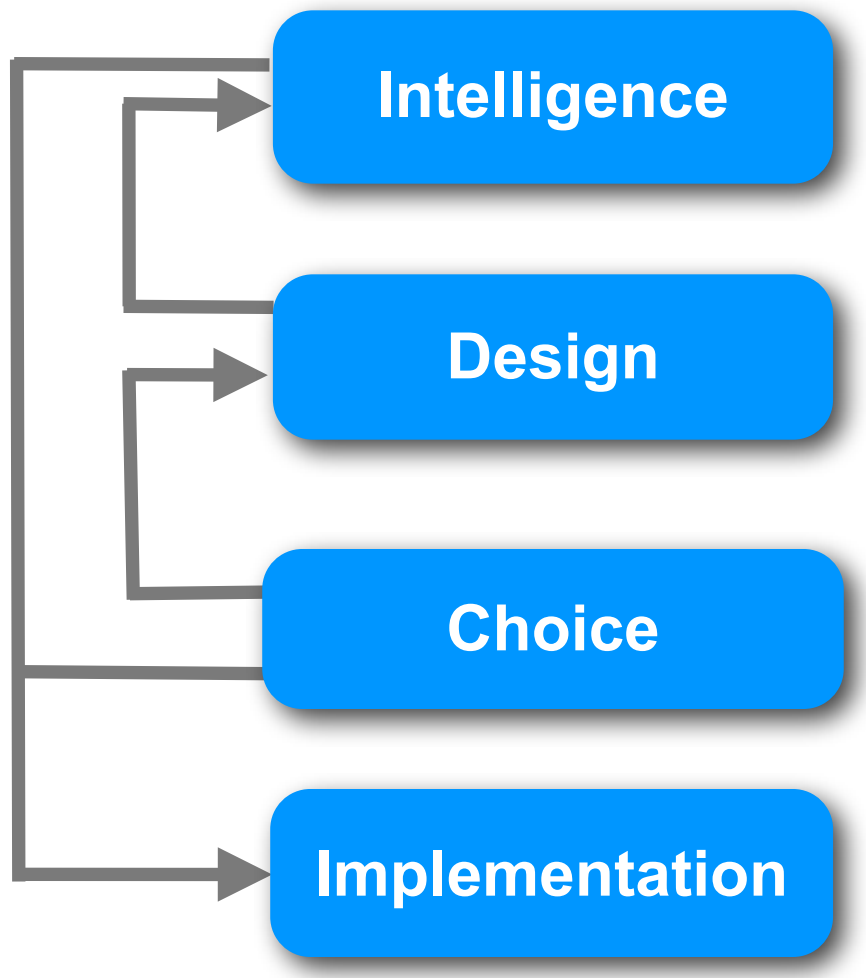
Mental models are not enough

- Dynamically complex problems require management aids to tackle them
- One man shows don't work any longer
  - **inter**disciplnary **experts** work together
  - on **trans**disciplinary **problems**
- Tools are needed to support all stages of decision making

Environmental Decision Support Systems (EDSS)

What are EDSS:
driving the decision making process

Decision making: an iterative process



Planning

Management

Simon (1960)

What is a DSS?

- Very generic term, many definitions
- **“Interactive computer-based system** that helps decision makers in the solution of **unstructured problems**” [Scott-Morton 1971]

Structure in problems

Structured	Semi-structured	Unstructured
The solution can be packaged in a computer program	A solution can be found, on the basis of previous experience, with small adaptation	General problem solving strategies: - analogy - redefinition - intuition - approximation

Decision support framework (Gary and Scott-Morton)

	Operational Control	Managerial Control	Strategic Planning	Technology support
Structured	Accts. Recviable Order Entry	Budget analysis Short-term forecasting Personnel Reports	Investment analysis Warehouse location	MIS, Operations research models, Transaction processing systems
Semi Structured	Production scheduling Inventory control	Credit evaluation Plant layout Project scheduling	Building new plants Mergers and acquisitions New product planning	DSS
Unstructured	Selecting magazine cover Buying software, Approving loans	Negotiation, executive recruiting	R&D planning New technology development	DSS EIS Machine learning
Technology support	MIS Management science	Mgt. Science DSS EIS ES	EIS ES Machine learning	

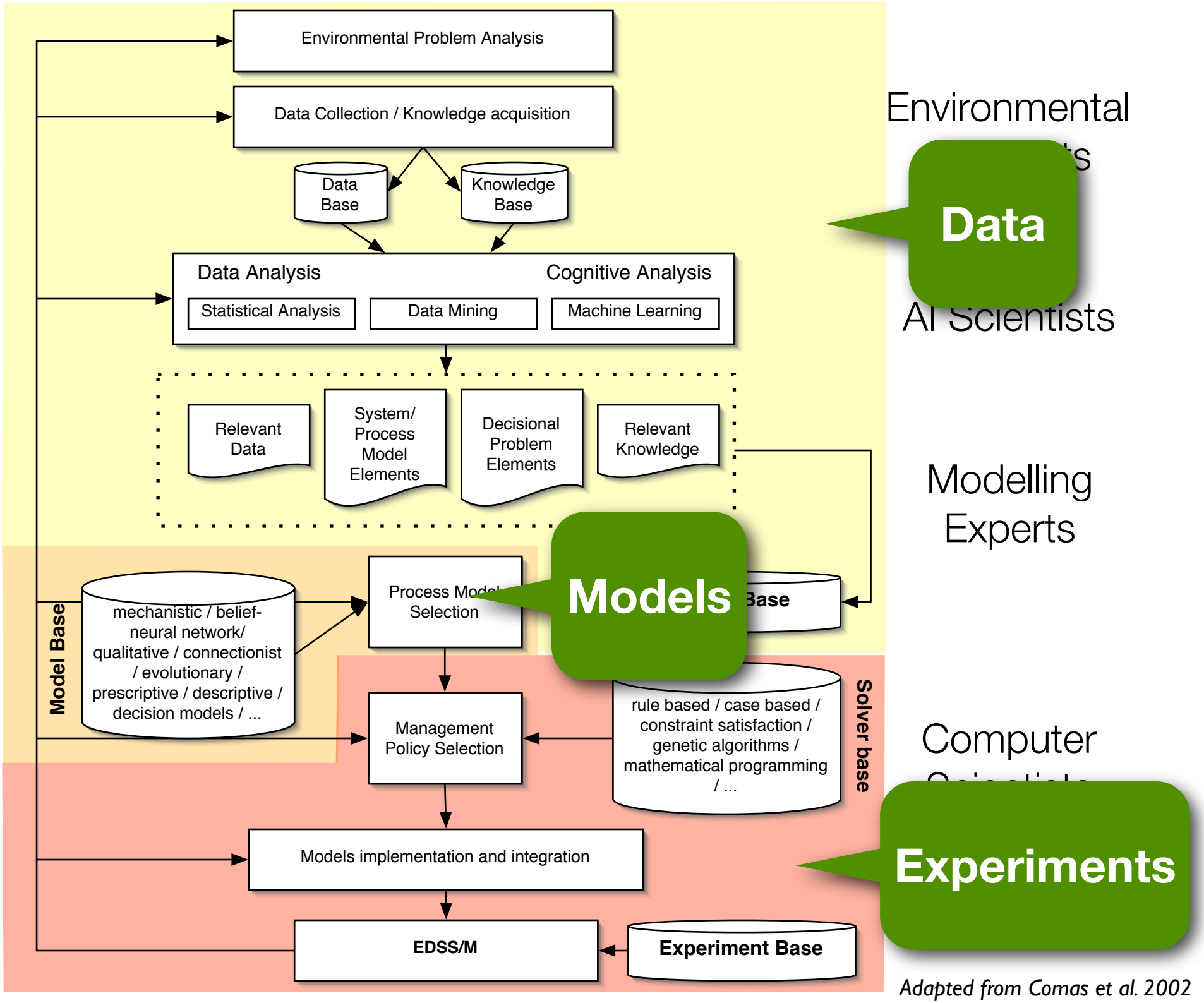
EDSS: a definition

- An EDSS is “a **computer-based interactive system**, helping the decision makers in the use of data and model to search for a solution to a **natural resource(s) management problem**”

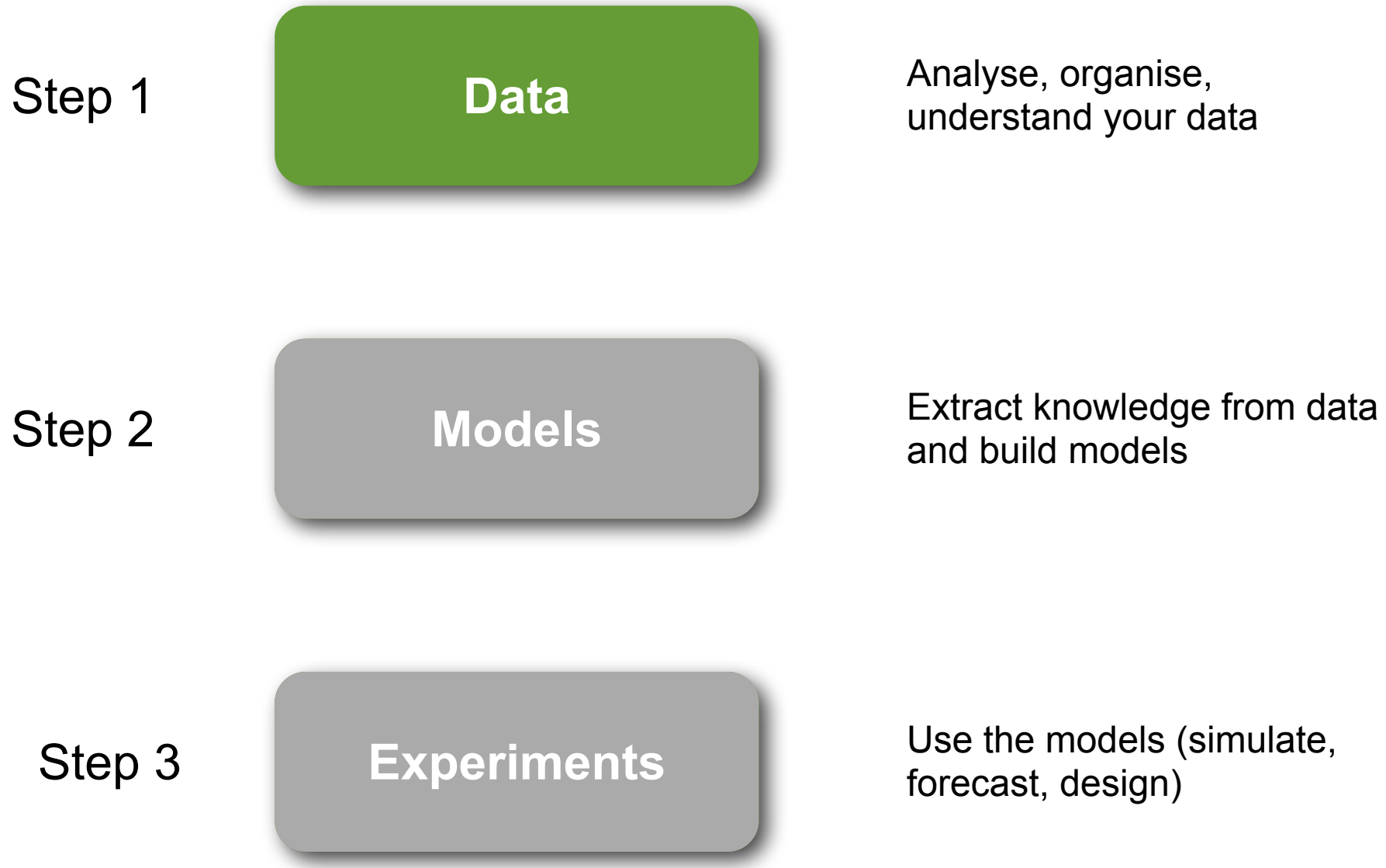
- An EDSS is an **intelligent information system** that reduces the time in which decisions are made in an **environmental domain**, and improves the consistency and quality of those decisions [Haagsma & Johanns, 1994]

- An EDSS is a **computer system** that assists decision makers in choosing between alternative beliefs or actions by applying knowledge about the decision domain to arrive at recommendations for the various options. It incorporates an explicit decision procedure based on a set of theoretical principles that **justify the “rationality” of this procedure** [Fox & Das, 2000]

How EDSS are implemented

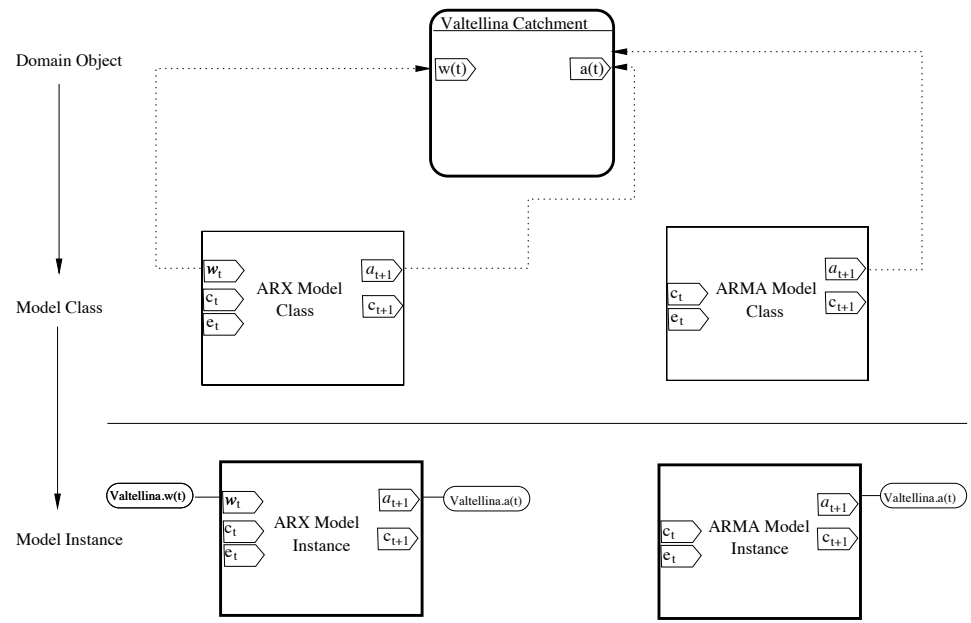


Adapted from Comas et al. 2002


Step 1
Data
Analyse, organise, understand your data
Step 2
Models
Extract knowledge from data and build models
Step 3
Experiments
Use the models (simulate, forecast, design)

Step 1: Data

- EDSS are **data intensive**
- Data are available at different spatio-temporal resolutions
- They are produced by multiple sources (sensors, field campaigns, aggregated statistical analyses, surveys)
- The **domain base** provides an abstract representation of data to the EDSS
  - bridge between the DMBS and the EDSS
  - usually implemented as a set of classes

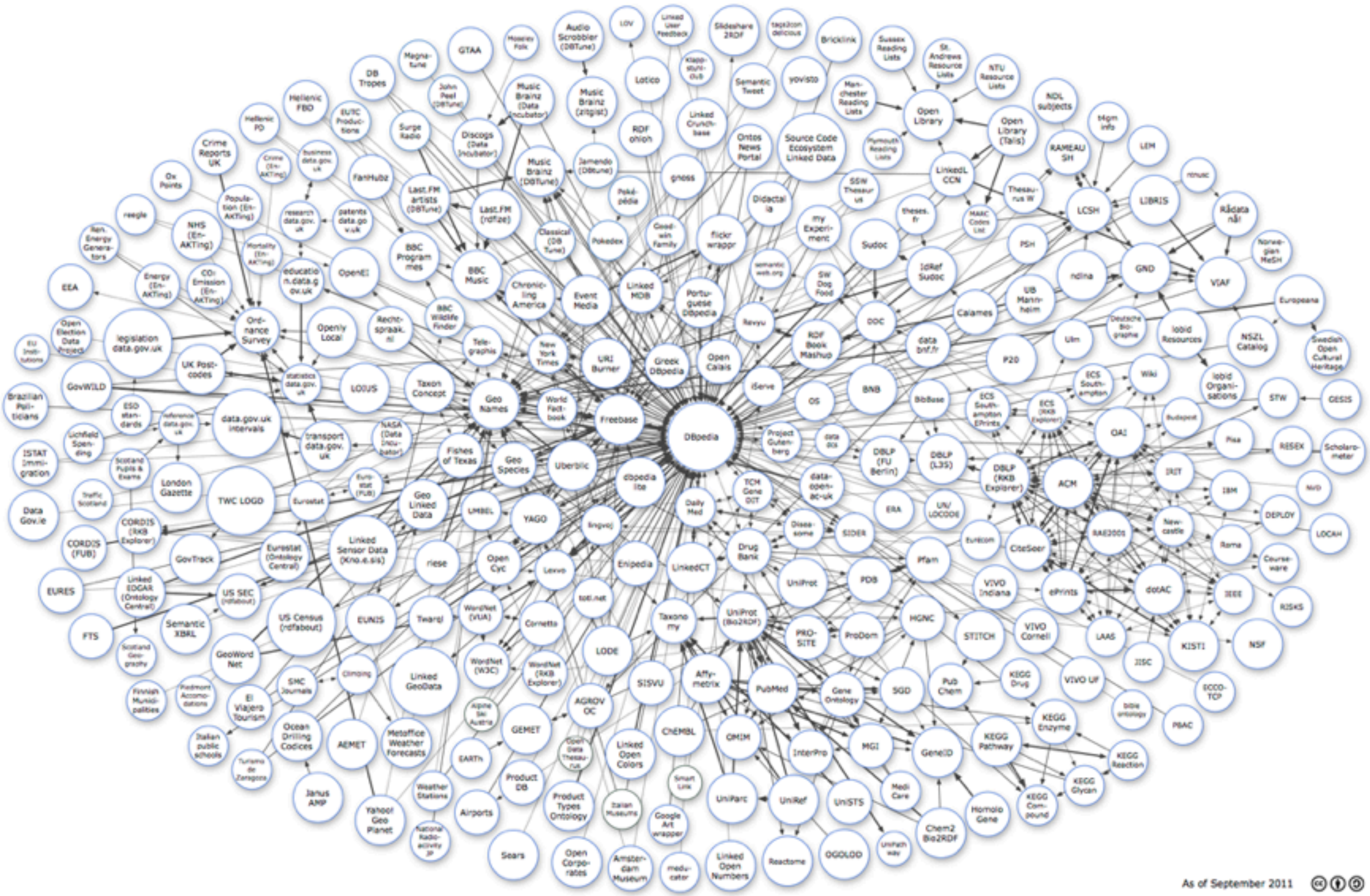


Step 1: Data

- Data are usually stored in diverse and sparse databases

- The push towards standardisation has been massive
  - the **Open Geospatial Consortium**: http://www.opengeospatial.org/standards/is
    - Sensor Observation Service
    - Sensor Web Enablement
    - WaterML
    - and many more

- The **Open Data** initiative http://www.opendatainitiative.org



As of September 2011

http://lod-cloud.net

Data: how to retrieve them

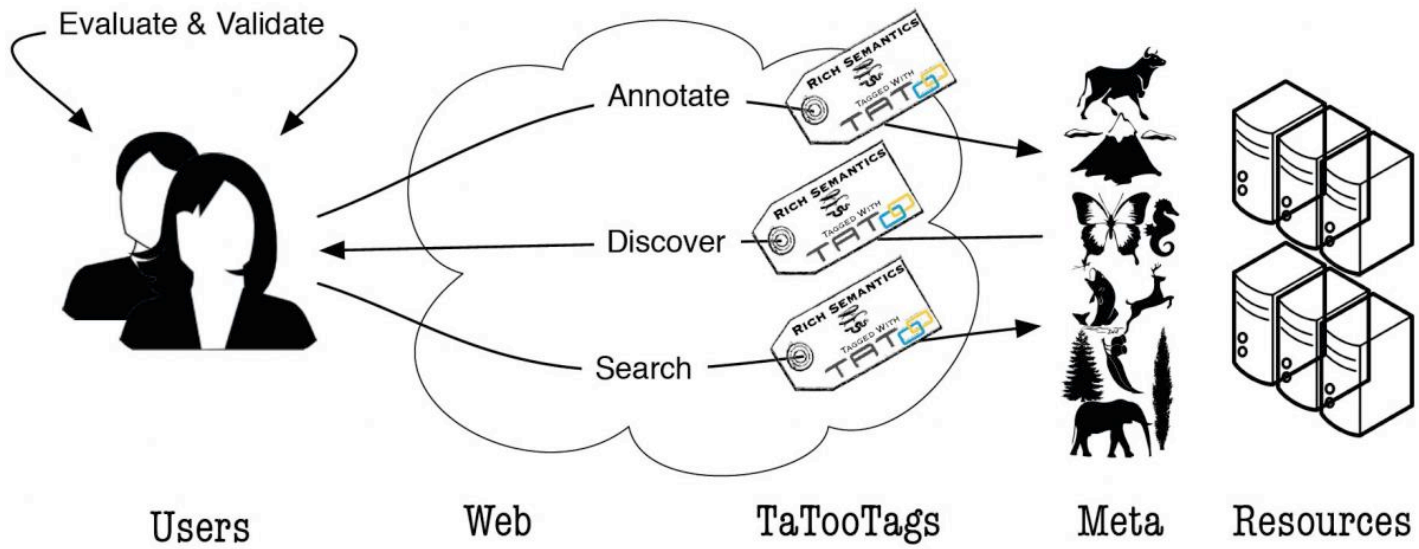
- **Web Services** provide a great way to access data on the internet
  - the are just function calls on the web
  - Use XML + HTTP
  - WSDL: a web service must comply to a published standard to be effectively used
  - UDDI: web services must be discoverable

- Some papers
  - Schimak, G., Rizzoli, A. E., & Watson, K. (2010). **Sensors and the environment – Modelling & ICT challenges**. Environmental Modelling & Software. doi:10.1016/j.envsoft.2010.03.022
  - Granell, C., Díaz, L., & Gould, M. (2010). **Service-oriented applications for environmental models: Reusable geospatial services.** Environmental Modelling & Software, 25(2), 182–198. doi:10.1016/j.envsoft.2009.08.005
  - Huang, M., Maidment, D. R., & Tian, Y. (2011). **Using SOA and RIAs for water data discovery and retrieval**. Environmental Modelling & Software, 26(11), 1309–1324. doi:10.1016/j.envsoft.2011.05.008
  - Nativi, S., Mazzetti, P., & Geller, G. N. (2013). **Environmental model access and interoperability: The GEO Model Web initiative**. Environmental Modelling & Software, 39, 214–228. doi:10.1016/j.envsoft.2012.03.007

Data: we need semantics, syntax is not enough

- **Ontologies**
  - An ontology is a specification of a conceptualization (Tom Gruber, 1992)
- Ontologies originate from Semantic Networks and related work on knowledge representation in AI
- They have become very popular thanks to their implementation by means of
  - RDF: resource description format
  - OWL: ontology web language

- We can use ontologies to **associate meaning with data**
  - **Modelling with knowledge: A review of emerging semantic approaches to environmental modelling** Environmental Modelling & Software, Volume 24, Issue 5, May 2009, Pages 577-587 Ferdinando Villa, Ioannis N. Athanasiadis, Andrea Emilio Rizzoli
  - Athanasiadis, I. N., Rizzoli, A. E., Donatelli, M., & Carlini, L. (2011). **Enriching environmental software model interfaces through ontology-based tools**. International Journal of Advanced Systemic Studies, 4(1/2), 94–105. doi:10.1504/IJASS.2011.042205
  - Rizzoli, A. E., Donatelli, M., Athanasiadis, I. N., Villa, F., & Huber, D. (2008). **Semantic links in integrated modelling frameworks**. Mathematics and Computers in Simulation, 78, 412–423. http://dx.doi.org/10.1016/j.matcom.2008.01.017



http://www.tatoo-fp7.eu

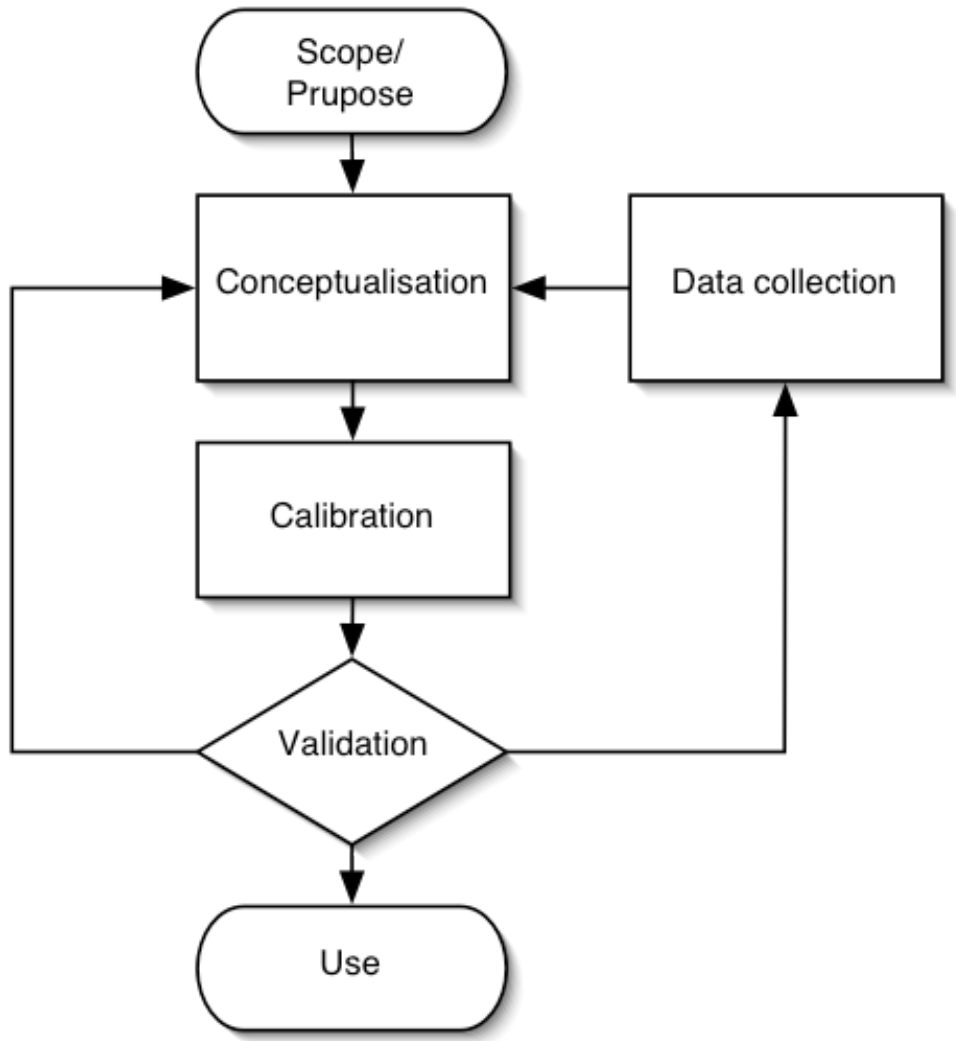

Meine Bank

Step 2: Models

Data

Models

Experiments



Models: supporting their development

- The role of **Environmental Integrated Modelling Frameworks (EIMF)**
  - "a set of **software libraries, classes and components**, which can be (re-)used to assemble and deliver an EDSS to support modelling and processing of environmental knowledge and to enhance the ***re-usability*** and ***distribution*** of such knowledge." [Rizzoli et al. 2008]

- Different focus:
  - EMF for linking: OpenMI http://www.openmi.org
  - EMF for model development: OMS http://www.javaforge.com/project/oms
  - EMF for model reuse: BioMA http://goo.gl/eJ2ju
  - EMF for spatio temporal modelling: PCRaster http://pcraster.geo.uu.nl
  - ... and many others ...

Some references

- On **EIMF**:
  - Rizzoli, A. E., Leavesley, G., II, J. C. A., Argent, R. M., Athanasiadis, I. N., Brilhante, V., Claeys, F. H. A., et al. (2008). **Integrated Modelling Frameworks for Environmental Assessment and Decision Support**. In A. J. Jakeman, A. A. Voinov, A. E. Rizzoli, & S. H. Chen (Eds.), Environmental Modelling, Software, and Decision Support - State of the Art and Future Perspectives (Vol. 3). Elsevier.

- EM&S TI: **Emulation techniques for the reduction and sensitivity analysis of complex environmental models**
  - Volume 34, Pages 1-116 (June 2012)
    Edited by Marco Ratto, Andrea Castelletti and Andrea Pagano
    http://www.sciencedirect.com/science/journal/13648152/34/supp/C

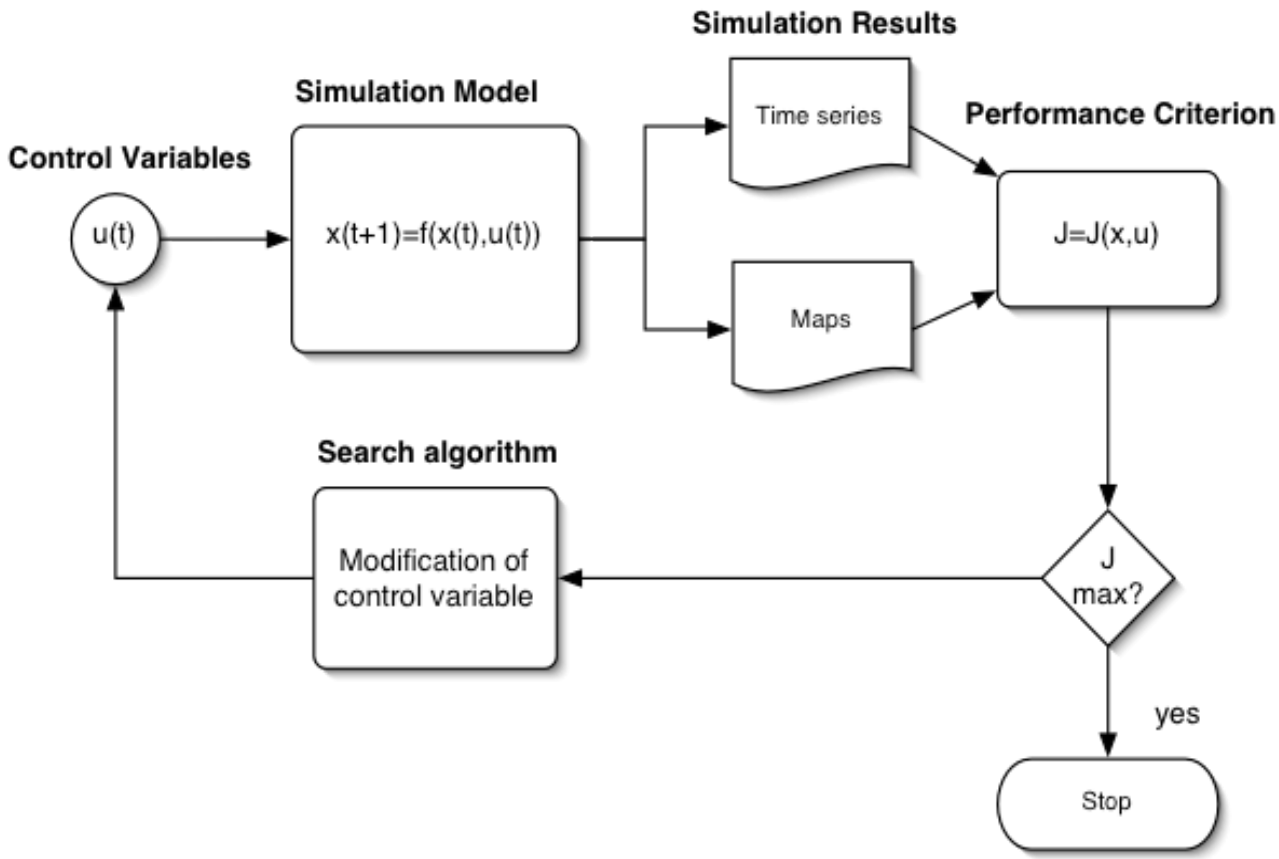
- EM&S TI: **The Future of Integrated Modeling Science and Technology**
  - Volume 39, Pages 1-330 (January 2013)
    Edited by Gerard F. Laniak, Andrea E. Rizzoli and Alexey Voinov
    http://www.sciencedirect.com/science/journal/13648152/39/supp/C

Step 3: Experiments

Data

Models

Experiments



Step 3: Experiments

- The EDSS should support the **design** of decision making **choices** and **policies**
- It should support the use of **simulation** and **optimisation** algorithms
- It should support **sensitivity analysis** and **design of experiments**
- It should support the **statistical analysis** of results
- It should promote the **involvement of stakeholders** in all of above

Step 3: Experiments

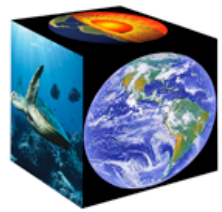
- The previously cited TI on **Model Emulation and Sensitivity Analysis**
- EM&S TI: **Modelling with Stakeholders**
  - Volume 25, Issue 11, Pages 1267-1488 (November 2010)
    Edited by François Bousquet and Alexey Voinov
    http://www.sciencedirect.com/science/journal/13648152/25/11
- Many **papers** such as:
  - A procedural approach to strengthening integration and participation in water resource planning Environmental Modelling & Software, Volume 21, Issue 10, October 2006, Pages 1455-1470, A. Castelletti, R. Soncini-Sessa
  - An integrated assessment tool to define effective air quality policies at regional scale Environmental Modelling & Software, Volume 38, December 2012, Pages 306-315 Claudio Carnevale, Giovanna Finzi, Enrico Pisoni, Marialuisa Volta, Giorgio Guariso, Roberta Gianfreda, Giuseppe Maffeis, Philippe Thunis, Les White, Giuseppe Triacchini
- Or try a **Google Scholar Search** such as:
  - http://scholar.google.com/scholar?q=multi-objective+management+of+natural+resources
  - (many advanced search options available...)

Step 3: the cyberinfrastructure

- From Wikipedia:
  - United States federal research funders use the term cyberinfrastructure to describe research environments that support advanced **data acquisition**, **data storage**, **data management**, **data integration**, **data mining**, **data visualization** and other **computing and information processing services** distributed over the Internet beyond the scope of a single institution.

- Examples
  - iemHUB for integrated environmental modelling: http://iemhub.org

  - EarthCube A Community-Driven Data and Knowledge Environment for the Geosciences http://earthcube.ning.com



EarthCube

How EDSS will work: the near future

GPUs

- More and more complex models can be run efficiently on new hardware and software infrastructures:
  - graphic processing units (GPUs) are cheap and extremely performing for parallel computation
  - using the CUDA environment (https://developer.nvidia.com/what-cuda) it is possible to write and compile code to run on GPUs
  - Some examples:
    - A high performance GPU implementation of Surface Energy Balance System (SEBS) based on CUDA-C Environmental Modelling & Software, Volume 41, March 2013, Pages 134-138. Mohammad Abouali, Joris Timmermans, Jose E. Castillo, Bob Z. Su
    - High-performance computing tools for the integrated assessment and modelling of social–ecological systems Environmental Modelling & Software, Volume 39, January 2013, Pages 295-303. Brett A. Bryan
    - Simulation of surface fire fronts using fireLib and GPUs Environmental Modelling & Software, Volume 38, December 2012, Pages 167-177 F.A. Sousa, R.J.N. dos Reis, J.C.F. Pereira

Cloud computing

- Cloud computing means computing resources efficiently shared
  - storage, applications, and services
  - direct mapping to EDSS functions: data/models/algorithms
  - Various models: IaaS, NaaS, PaaS, SaaS

- Various vendors offer solutions
  - Google AppEngine https://developers.google.com/appengine/
  - Amazon Web Services http://aws.amazon.com
  - Windows Azure http://www.windowsazure.com/en-us/

- Examples
  - Enabling collaborative decision-making in watershed management using cloud-computing services Environmental Modelling & Software, Volume 41, March 2013, Pages 93-97 Alexander Sun
  - Leveraging the capabilities of service-oriented decision support systems: Putting analytics and big data in cloud Decision Support Systems, Volume 55, Issue 1, April 2013, Pages 412-421Haluk Demirkan, Dursun Delen

WolframAlpha computational knowledge engine

global CO2 level

Examples Random

Assuming the input is referring to global climate studies | Use "global" as all countries instead

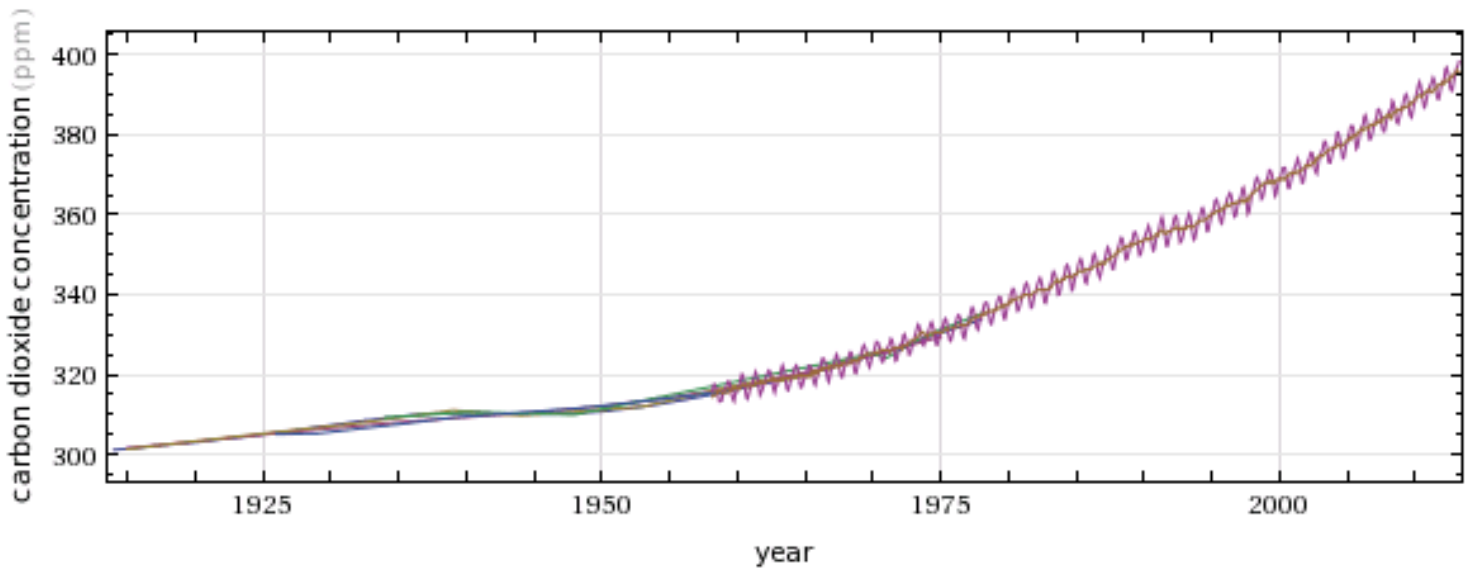
Input interpretation:

global carbon dioxide concentration

Results:

All All models Last 100 yr

History:



Description: Details

Google

CO2 concentration

Tables experimental

Results 1 - 10 of about 20,152 for CO2 concentration. (0.19 seconds)

Web

Web Tables

Fusion Tables

Send Feedback

Carbon dioxide in Earth's atmosphere - Wikipedia, the free ...

http://en.wikipedia.org/wiki/**Carbon_dioxide**_in_Earth's_atmosphere

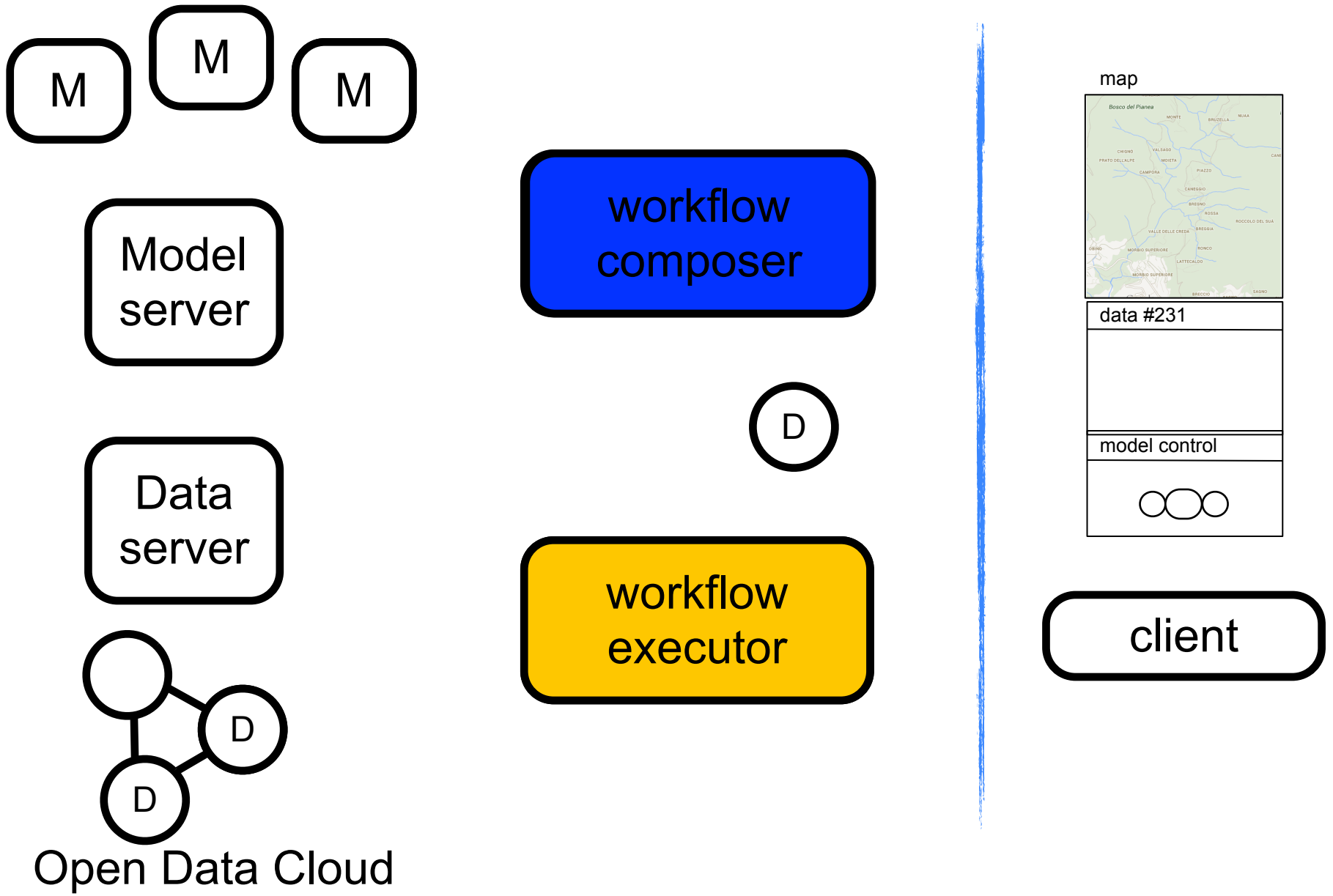
country | china | united states | russia

Show less (11 rows / 5 columns total) - Import data

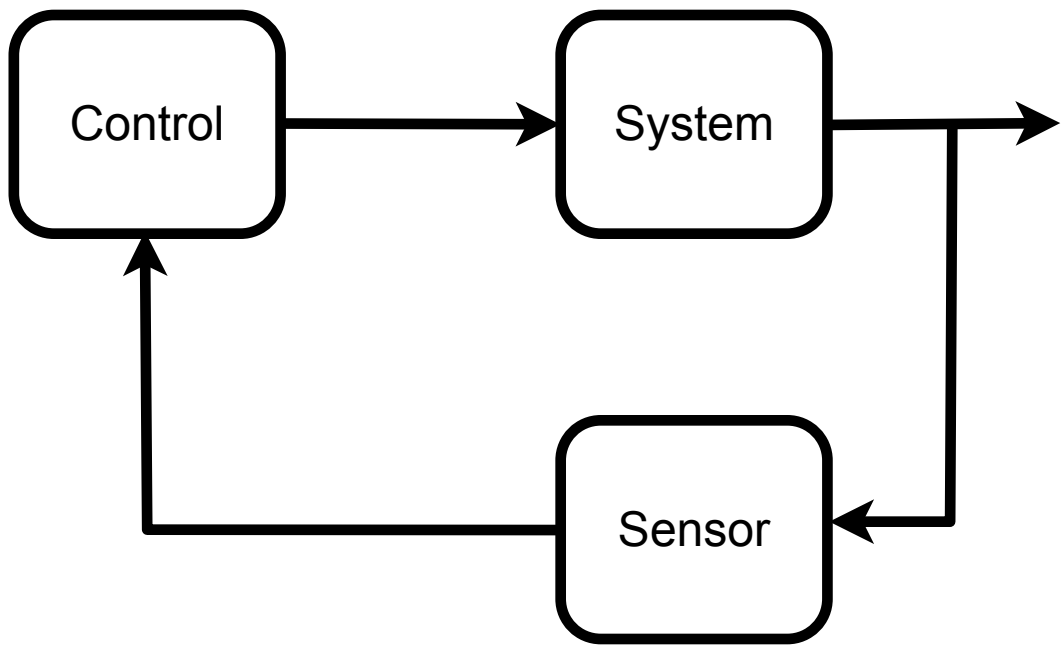
Country	Carbon dioxide emissions	Percentage of global	Avg. emission per	Carbon dioxide emissions
China	6,103	21.5%	636	4.9
United States	5,752	20.2%	597	19.3
Russia	1,564	5.5%	91	11.6
India	1,510	5.3%	459	1.4
Japan	1,293	4.6%	3421	9.8
Germany	805	2.8%	2254	9.6
United Kingdom	568	2.0%	2338	8.9
Canada	544	1.9%	54	16.5
South Korea	475	1.7%	4758	10.5
Italy	474	1.7%	1573	7.7

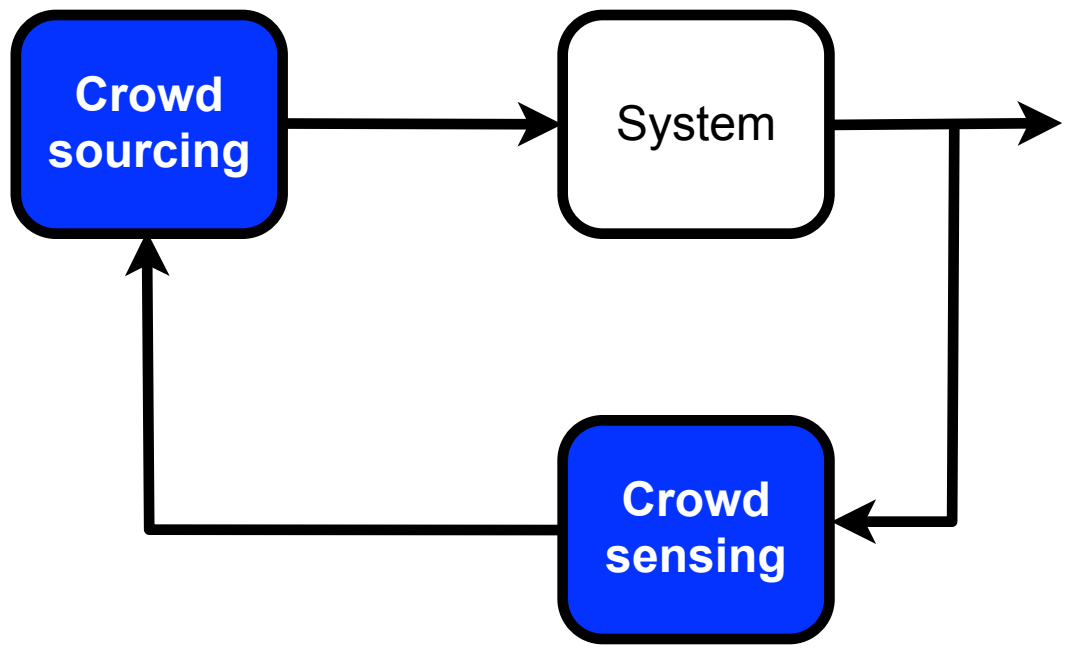
Google Fusion Tables http://www.google.com/drive/apps.html#fusiontables

A possible EDSS architecture in the cloud



The missing link


Control
System
Sensor



Putting humans in the loop: Social computing for Water Resources Management
Environmental Modelling & Software, Volume 37, November 2012, Pages 68-77
P. Fraternali, A. Castelletti, R. Soncini-Sessa, C. Vaca Ruiz, A.E. Rizzoli

User involvement: crowdsensing

- Most traditional and straightforward application
  - smartphone as sensors
  - “Red Balloon” experiment
    http://en.wikipedia.org/wiki/DARPA_Network_Challenge

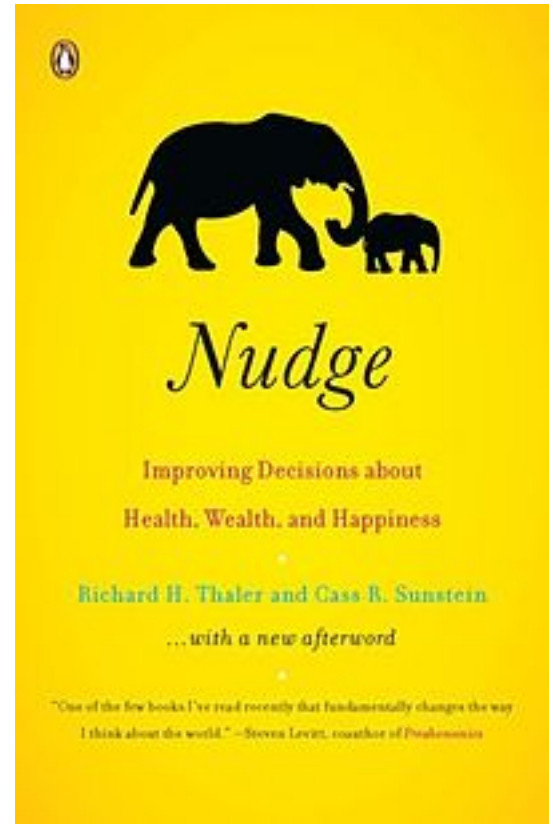
- Stakeholders are the public, no mediation
  - need for filtering information and feedback

- Crowdsensing can be voluntary or non-voluntary (e.g. PRISM)

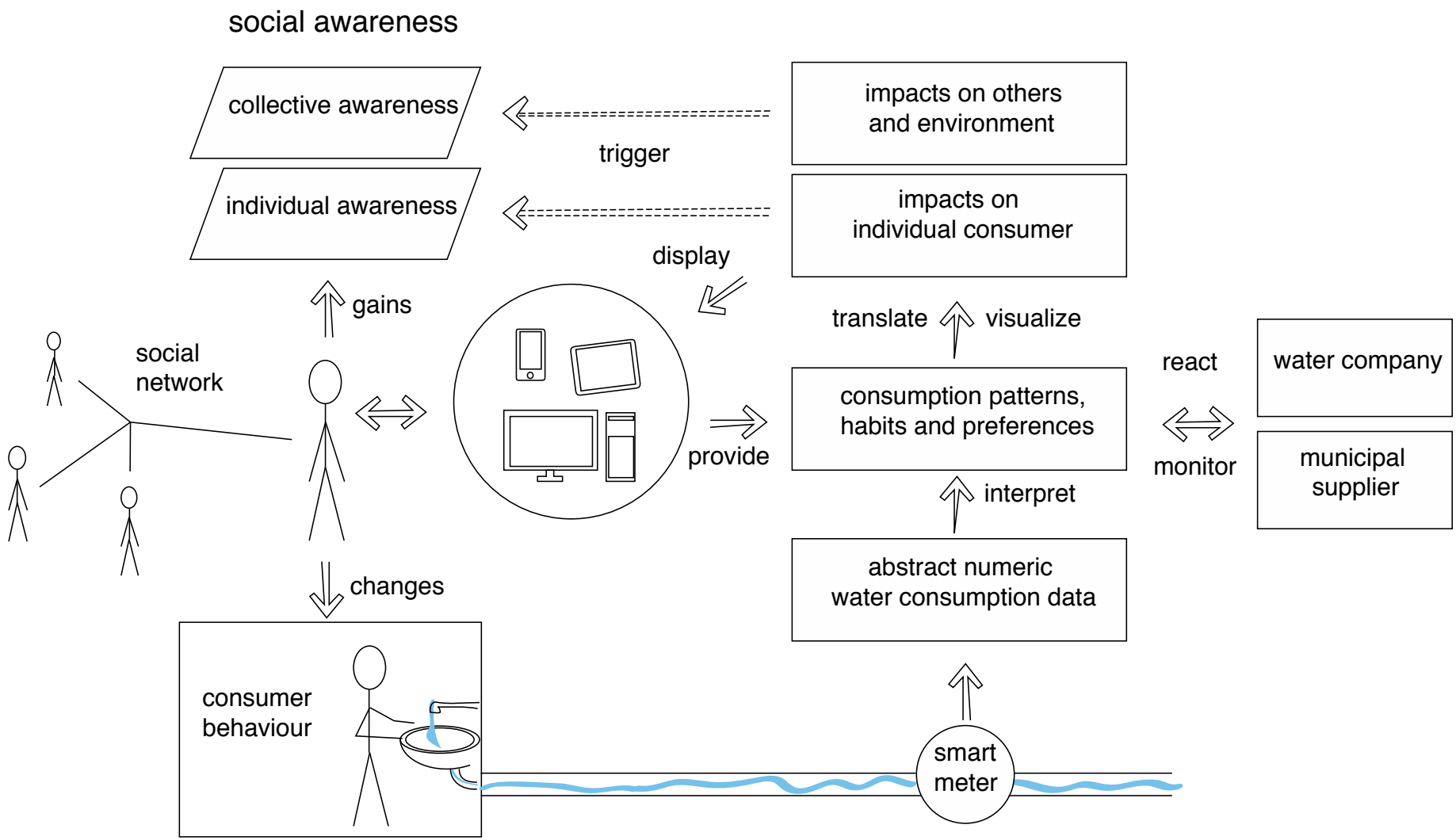
- Examples:
  - use text mining to discover the public “sentiment” about a proposed WWTP plant
  - use text mining to detect a problem about odours caused by malfunctions in the plant

User involvement: crowdsourcing

- Use people as actuators and regulators
- People can directly **act according to instructions** received
  - e.g. Amazon Mechanical Turk
    https://www.mturk.com/mturk/
- People can be **stimulated to change their behaviour**, thus making an impact on the system
  - e.g. H2omeSmart program in Perth
    http://www.watercorporation.com.au/save-water/rebates-programs/h2ome-smart



Nudge: Improving Decisions about Health, Wealth, and Happiness. Thaler and Susstein. 2008. Yale University Press


social awareness
collective awareness
individual awareness
trigger
impacts on others and environment
impacts on individual consumer
display
gains
social network
translate
visualize
react
water company
consumption patterns, habits and preferences
provide
monitor
municipal supplier
interpret
abstract numeric water consumption data
changes
consumer behaviour
smart meter

How EDSS are used: a survey

A review of 100 papers over a 10 year period (2001-2011)

- Environmental Modelling & Software publishes contributions, in the form of research articles, reviews, short communications as well as software and data news, on recent advances in environmental modelling

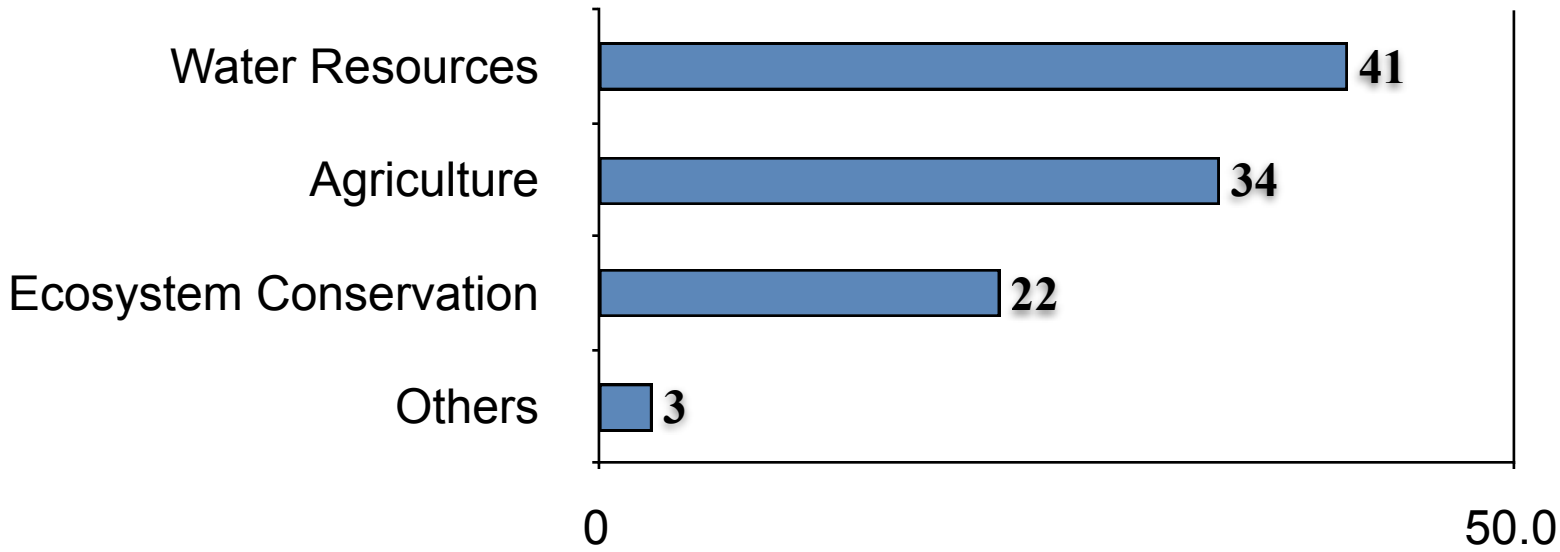
- In 2007 we ran a Thematic Issue on **Environmental Decision Support Systems**

  Volume 22, Issue 2, Pages 123-278 (February 2007)
  Edited by Michael Matthies, Carlo Giupponi
  and Bertram Ostendorf
  http://www.sciencedirect.com/science/journal/13648152/22/2

- We kept on publishing similar papers which are central to the scope of the journal

- We published our analysis in:
  - Sojda, R. S., Chen, S. H., Sawah, S. El, Joseph, H. A., Jakeman, A. J., Lautenbach, S., Mcintosh, B. S., et al. (2012). **Identifying the decision to be supported : a review of papers from Environmental Modelling and Software**. IiEMSs 2012 International Congress on Environmental Modelling and Software, Sixth Biennial Meeting, Leipzig, Germany (pp. 73–80). Leipzig, Germany: iEMSs, Manno, Switzerland.

EDSS: areas of application



- Water resources
  - quality, quantity, urban, peri-urban, WWTP, groundwater etc
- Agriculture irrigation, soil management, etc
- Ecosystem conservation fish, wildlife, protected areas
- Others: Climate mitigation and adaptation, Air quality, Land use planning, urban planning

EDSS: use in decision process

- **Only 60% of the papers clearly identified the decision to be supported**:
  - domain of application
  - decision making context (strategic planning vs management)
  - spatial and temporal context (regional/local/national/global - hours/days/weeks/years)

- To identify the decision to be supported ...
  - 25% used expert opinion
  - 14% sole judgement of authors
  - 13% focus groups
  - 8% formal surveys
  - 52% no method explicitly described

Participation

- Participatory decision making
  - Bottom-up, from stakeholders to policy makers
  - Spread information
  - Enhance transparency
  - Promote active involvement of stakeholders
  - Evaluation for negotiation: find the best compromise

- **In 65% of the cases experts with no real stake were involved**

- In 23% of the case end users were involved

- 53% of the papers did not explicitly mention at which stage the stakeholders were involved, if at all

The decision type

- 61% of the paper focussed on **strategic** decisions
  - impacts with an horizon greater than one year
- 21% with an horizon between one week and one year
- 12% with an horizon shorter that one week
- **35% unclear**
- Most of the strategic planning papers were nevertheless aimed at **local** and **regional** problems

Our conclusions

- There is a **lack of uniformity** on reporting the results of a study involving a DSS
- The context and the objectives are often **not adequately described**
- It is essential to **clearly identify which decisions are to be supported** and to **define performance indicators** to measure the effectiveness of the DSS
- EDSS are great tools, but it is important to use them properly.

Thank You